

NASA Contractor Report NASA/CR-2009-214763



Situational Lightning Climatologies for Central Florida: Phase IV

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April 2009

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Acknowledgements

The author wishes to thank Mr. Tim Oram of the Spaceflight Meteorology Group (SMG) and Mr. William Roeder of the 45th Weather Squadron for their efforts to acquire the individual lightning strike data from the 14th Weather Squadron (14 WS) Strategic Climatic Information Service and National Climatic Data Center. Without the individual strike data this task would not have been possible. Additionally, the 14 WS delivered the data in a format that significantly reduced processing time by the AMU.

The author also thanks Ms. Winnie Crawford of the Applied Meteorology Unit for her help explaining the fundamentals of the S-PLUS® software and assisting with creating and editing S-PLUS scripts to process the enormous amount of lightning data required to complete this work.

Finally, the author thanks Mr. Richard Lafosse of SMG and Mr. Matthew Volkmer of the National Weather Service in Melbourne (NWS MLB) for their reviews of the data and methodology that provided the key to producing the most operationally useful product and to Mr. Volkmer, Mr. David Sharp of NWS MLB, Mr. Brian Hoeth and Mr. Kurt Van Speybroeck of SMG for review and testing of the graphical user interface.

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Executive Summary

The threat of lightning is a daily concern during the warm season in Florida. Research has revealed distinct spatial and temporal distributions of lightning occurrence that are strongly influenced by large-scale atmospheric flow regimes (Lericos et al. 2002). In the previous phase, the AMU calculated the probability of lightning climatologies using gridded lightning data and the flow regimes as in Lambert et al. (2006) for 1-, 3- and 6-hr intervals in 5-, 10-, 20-, and 30-NM diameter range rings around the Shuttle Landing Facility (SLF) and eight other airfields in the National Weather Service in Melbourne (NWS MLB) county warning area (CWA). These climatologies were made available to forecasters in a graphical user interface for quick and easy access.

In this phase, the AMU recalculated the lightning climatologies for the SLF and the eight airfields in the NWS MLB CWA using individual lightning strike data to improve the accuracy of the climatologies. The AMU also updated the graphical user interface (GUI) with the new data. As in the previous phase, the AMU stratified the climatologies for each location by time interval, distance and flow regime. New for this phase, the AMU included all data regardless of flow regime as one of the stratifications, added monthly stratifications, used modified flow regimes as described in Lambert (2007), and added three years of data to the period of record.

The AMU used individual strike data from the National Lightning Detection Network (NLDN) instead of NLDN gridded lightning data to create more accurate climatological values for each range ring than was possible with the gridded data set. Individual strike data had the following advantages over gridded data:

- Simplified the data processing,
- Provided more accurate climatologies, and
- Did not require estimating circular range rings from square grids.

In addition, to better meet customer requirements, the AMU made changes such that the 5- and 10-NM radius range rings are consistent with the aviation forecast requirements at NWS MLB, while the 20- and 30-NM radius range rings at the SLF assist SMG in making forecasts for weather Flight Rule violations of lightning occurrence during a Shuttle landing.

The NLDN individual lightning strike data were provided to the 45th Weather Squadron by the 14th Weather Squadron (14 WS) Strategic Climatic Information Service for use by the AMU staff. The NLDN database contains lightning strike data provided to the 14 WS by Vaisala Inc., in Tucson AZ. The 14 WS customized the dataset for the AMU and provided files that included the date, time, latitude and longitude, polarity and strength of every strike within a 30 NM radius of the center of the runway for each site and included the years 1989-2007.

The results were presented in tabular and graphical format and incorporated into a web-based GUI so forecasters could easily navigate through the large amount of data. The GUI's HyperText Markup Language format makes it usable in most web browsers on computers with different operating systems.

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Table 1. This table contains the names of each flow regime as reclassified by the AMU, the definition of each flow regime, and the number of days in each regime during the warm seasons in 1989–2007 11

1. Introduction

The threat of lightning is a daily concern during the warm season in Florida. The forecasters at the Spaceflight Meteorology Group (SMG) at Johnson Space Center in Houston, TX consider lightning in their landing forecasts for Space Shuttles at the Kennedy Space Center (KSC), FL Shuttle Landing Facility (SLF). The forecasters at the National Weather Service in Melbourne, FL (NWS MLB) also consider lightning in their Terminal Aerodrome Forecasts (TAFs) for seven¹ airports in the NWS MLB County Warning Area (CWA). Figure 1 shows the location of the SLF and the NWS MLB TAF locations within the NWS MLB CWA in east-central Florida.

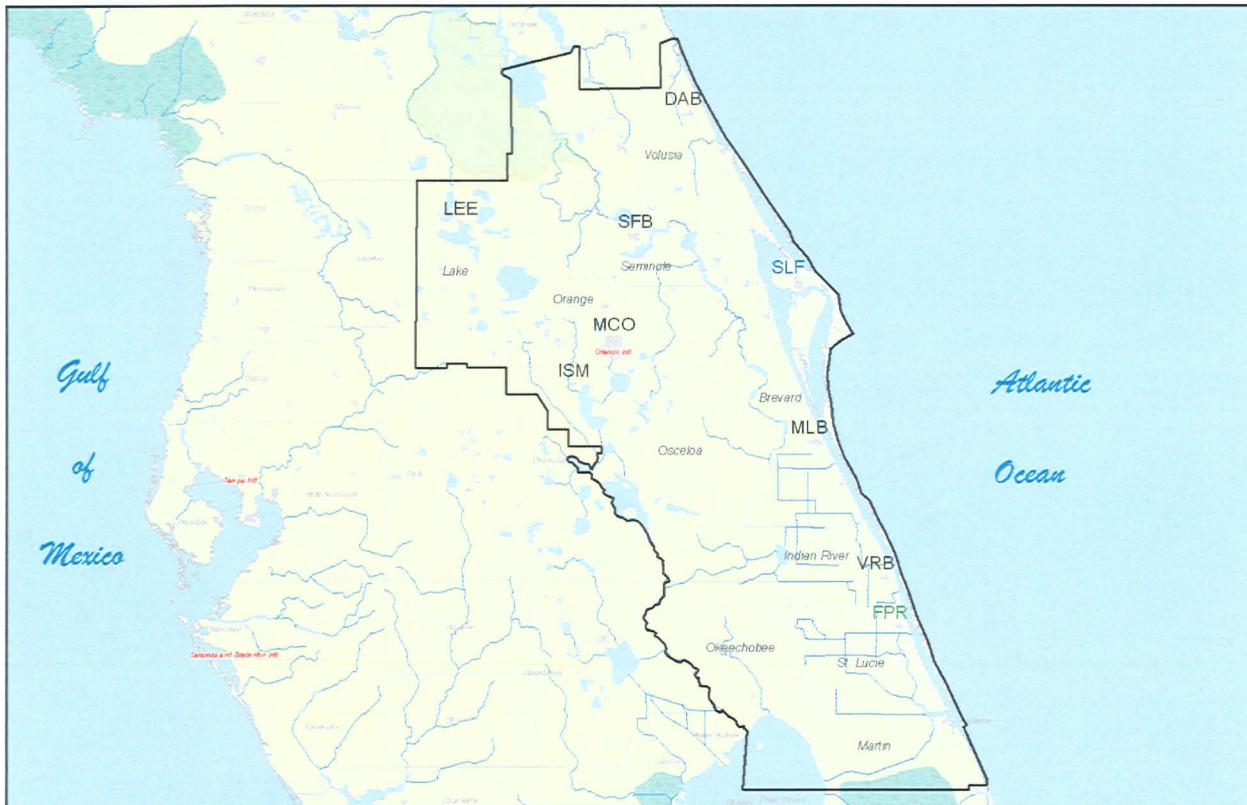


Figure 1. Map of central Florida showing the location of the SLF (blue text), the seven current NWS MLB TAF sites (black text), possible future NWS MLB TAF site (green text) and the NWS MLB CWA (heavy black outline area).

The threat of lightning is always a consideration for SMG forecasters during Shuttle landing operations. Lightning detected within 30 NM of the SLF violates weather Flight Rules (FR) for Shuttle landing operations. The NWS MLB creates a daily cloud-to-ground (CG) lightning threat index map for their CWA that encompasses all of their TAF locations. These daily maps are available on the NWS MLB web site at the URL <http://www.srh.weather.gov/mlb/ghwo/lightning.shtml>. The 45th Weather Squadron (45 WS) forecasters include a probability of lightning occurrence in their daily 24-Hour and Weekly Planning forecasts, which are briefed in the morning at 1100 UTC (0700 EDT). The probability of lightning occurrence is used by personnel involved in determining the possibility of violating launch commit criteria, and planning for daily ground operation activities on KSC and Cape Canaveral Air Force Station (CCAFS).

The work described in this report is Phase IV of this project. Work completed in the previous phases is described in Bauman (2007). The AMU created climatologies of lightning probabilities based on synoptic-scale flow regimes over the Florida peninsula (Lambert, 2007) for 5-, 10-, 20-, and 30-NM radius range rings around the SLF and the eight airports in 1-, 3-, and 6-hour increments. In addition to climatologies based on the flow regimes, the AMU created a climatology based on all the data combined (non-flow regime based) and stratified the data by warm

¹ At the request of NWS MLB, the AMU added an eighth airport, St. Lucie County International Airport (FPR), to this task because it may be added to their TAF responsibility in the future.

season month at the request of SMG. The sites in this task are the same as in the previous work and include the SLF, Daytona Beach (DAB), Leesburg (LEE), Sanford (SFB), Orlando International (MCO), Kissimmee (ISM), Melbourne (MLB), Vero Beach (VRB) and Fort Pierce (FPR) in east-central Florida. Figure 2 shows the locations of the nine sites with 5-, 10-, 20- and 30-NM radius range rings extending outward from the center of each runway. The 20- and 30-NM range rings at the SLF were chosen to create the climatologies that will assist SMG in making forecasts for FR violations of lightning occurrence during a Shuttle landing. The 5- and 10-NM range rings are consistent with the aviation forecast requirements at NWS MLB. The 20- and 30-NM range rings were included for the NWS MLB TAF sites at their request.

The work in this phase used individual cloud-to-ground (CG) lightning strike data from the National Lightning Detection Network (NLDN) to create more accurate climatological values for each range ring than was possible with the gridded data set used in the previous phase. Also, the size of the range rings around each site was adjusted since the range ring distances in the last phase were calculated as diameters, but should have been radii. The 10- and 20-NM diameter range rings were still useful for NWS MLB since they represented 5- and 10-NM radius range rings, but they were not useful for SMG. Also, using gridded lightning data required estimating circular range rings from square grids. This had resulted in over- and underestimating the lightning climatologies at each site, depending on the size of the range ring.

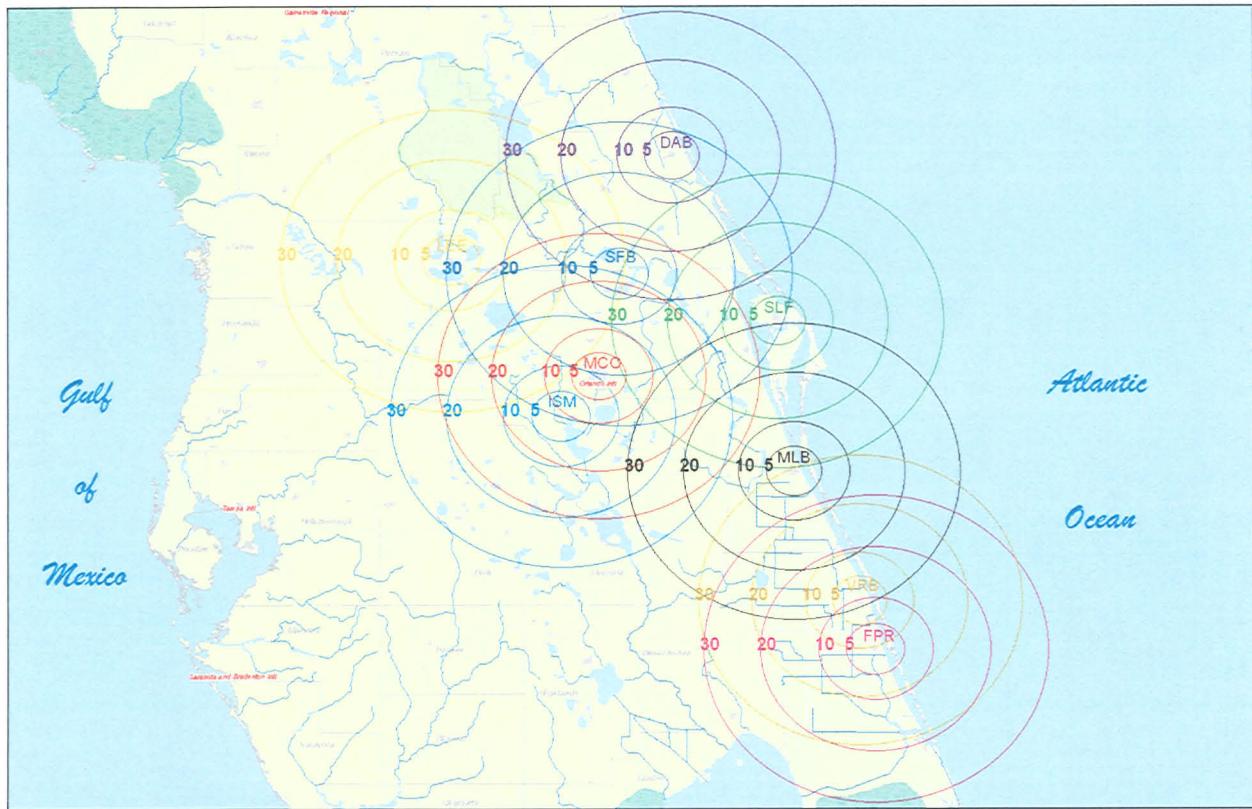


Figure 2. Map of central Florida showing locations of nine sites in the NWS MLB CWA surrounded by 5-, 10-, 20- and 30-NM radius range rings.

2. Data

Two types of data were needed for this task: the individual lightning strike data from NLDN and the dates on which each flow regime occurred. The AMU obtained the NLDN CG lightning strike data with assistance from SMG and the 45 WS. The flow regimes were obtained from an earlier AMU task described in Lambert (2007).

2.1 Lightning Data

The NLDN data were provided to the 45 WS by the 14th Weather Squadron (14 WS). The NLDN database contained lightning strike data provided to the 14 WS by Vaisala Inc. in Tucson AZ. The 14 WS provided data that included the date, time, latitude and longitude, polarity and strength of every strike within a 30 NM radius of each site for the entire period of record (POR). Having individual strike data in this format instead of the gridded data as in the previous phase simplified the data processing and provided more accurate climatologies.

The 14 WS provided the 45 WS with nine data files (one for each site) in comma separated value (.csv) format ranging in size from 80 to 134 MB per file. The files were too large to open in Microsoft Excel™ 2007 but could be opened and processed by S-PLUS® software (Insightful Corporation 2007). Using S-PLUS, the AMU removed the non-warm season months from each file and then wrote scripts in S-PLUS to create individual files for each site broken down by 1-, 3- and 6-hr time intervals and then by 5-, 10- and 20-NM range rings. The data added three years to the POR of the previous work and included the warm season months of May through September in the 19-year period 1989-2007.

2.2 Flow Regimes

The flow regimes used were modified from those in the previous work and were based on Lambert (2007). The method of determining the flow regime in previous work followed the procedure described in Lericos et al. (2002). It used the mean wind direction in the 1000–700 mb layer from the Jacksonville (JAX), Tampa (TBW), and Miami (MFL) 1200 UTC soundings. However, this method failed to classify the flow regime in 44% of the days in the POR. Lambert (2007) modified this method to include the 1000–700 mb mean wind direction in the 1000 UTC CCAFS (XMR) sounding. This wind direction was used to determine the flow regime when it could not be classified by using the combined wind directions from the other three soundings. Figure 3 shows the locations of the soundings used to determine the flow regime for each day in the POR.



Figure 3. The plus signs on the map show the locations of the soundings used to determine the flow regimes on each day in the POR.

The AMU had previously created data files containing all warm season flow regimes from 1989-2005. They added warm season flow regimes for 2006 and 2007 based on work conducted for the 45 WS by Dr. James Koerner of Plymouth State University. Table 1 shows the names of each flow regime based on the reclassification in 2007 by the AMU and includes a short definition of each flow regime and the number of days on which each flow regime occurred in the POR. Table 1 also shows the non-flow regime stratification requested by SMG named “All”, which contains all of the days in the data set. Therefore, the AMU calculated climatologies of lightning probabilities for a total of eight flow regimes.

Table 1. This table contains the names of each flow regime as reclassified in Lambert (2007), a brief definition of each flow regime, and the number of days in each regime during the warm seasons in 1989–2007.

<i>AMU Naming Convention</i>	<i>Flow Regime Definition</i>	<i># Days in Regime</i>
SW-1	Ridge south of MFL	331
SW-2	Ridge between MFL and TBW	682
SE-1	Ridge between TBW and JAX	486
SE-2	Ridge north of JAX	262
NW	Peninsular NW flow	363
NE	Peninsular NE flow	367
Other	Undefined Regime	339
All	Non-flow Regime Based	2830

3. Data Processing

The majority of the effort for this task involved combining and manipulating the raw NLDN and flow regime data files into formats easily manipulated by the software packages used to analyze the data. The end goal of the data processing was to output the statistics in a format that could be implemented in a graphical user interface (GUI).

3.1 Lightning Files

The 14 WS provided one .csv format file per site containing NLDN CG lightning strike data within 30 NM of the center of the runway for each site. The file for each site contained the date, time, latitude and longitude, peak current, polarity, bearing and distance from the center of the runway of every strike for the entire POR. Normally a .csv-formatted file can be opened as a spreadsheet in Excel, but each file surpassed the 1,048,576 row limit imposed by Excel 2007. Therefore, the AMU imported the .csv files into the S-PLUS software package to process the lightning data files. Upon doing so, S-PLUS reformatted the files into a proprietary format that uses an object class called a data frame to store matrix shaped data. These data can then be manipulated using the S-PLUS scripting language. Since only the warm season months of May-September were of interest for this task, the AMU first extracted the warm season months from each file. Using the new files containing only warm season NLDN data, the AMU processed each site's file and sorted them by year, month and day to prepare them to be merged with the flow regime data.

3.2 Flow Regime Files

The flow regime data were contained in five Excel spreadsheet files each representing one warm season month. Each of the five files contained three columns of data with year, day and flow regime. To prepare these files for merging with the lightning data, the AMU imported the files into S-PLUS and wrote an S-PLUS script to insert a column representing the numeric month into each file, merged the five files and then sorted the new file based on year, month and day.

3.3 Merged and Output Files

With the lightning and flow regime files in similar formats, the AMU wrote an S-PLUS script to merge each site's 30-NM range lightning data file with the flow regime file. The resulting merged file for each site contained the 30-NM range lightning strike data and its corresponding flow regime for each day in the POR.

The AMU wrote S-PLUS scripts to extract 1-, 3- and 6-hourly interval data from the merged file resulting in three time-interval based merged files for each site. Then, the AMU wrote S-PLUS scripts to create 5-, 10- and 20-NM range data files for each of the three time intervals. The resulting 108 files were then sorted by the eight flow regimes, creating 864 new files. Finally, stratifying the data by month resulted in a total of 4,320 data files in S-PLUS data frame format. However, the S-PLUS data frames are not compatible with the format needed to develop the GUI so the AMU wrote additional S-PLUS scripts to process and reformat the data frames and export them in Excel (.xls) format.

4. GUI Development

The AMU developed a web-based HyperText Markup Language (HTML) GUI that can be used with most web browsers on computers with popular operating systems (e.g., Windows, Mac and Linux). Both NWS MLB and SMG indicated a web-based HTML GUI would be compatible with their operations.

4.1 Excel Files

The Excel files exported from S-PLUS were not in a format conducive to GUI development. To put the data in a more presentable format for the forecasters, the AMU wrote Excel macros in Microsoft Visual Basic to merge the individual spreadsheets generated by S-PLUS into one warm season Excel 2007 workbook and five monthly Excel 2007 workbooks per site. Each workbook contained a worksheet for each of the eight flow regimes with 1-, 3- and 6-hour interval tables displaying the number of days with NLDN CG lightning, the climatological probability of lightning and corresponding probability charts for all time intervals and at 5-, 10-, 20- and 30-NM ranges (Figure 4). At the request of NWS MLB and SMG, the AMU fixed the y-axis to the same value for all charts of the same time interval for all sites based on the maximum value for each time interval for all sites. The forecasters stated fixing the y-axis to the maximum value would be operationally beneficial to them. The maximum y-axis values on the 1-hourly graphs were fixed at 70%, on the 3-hourly graphs at 80%, and on the 6-hourly graphs at 90%.

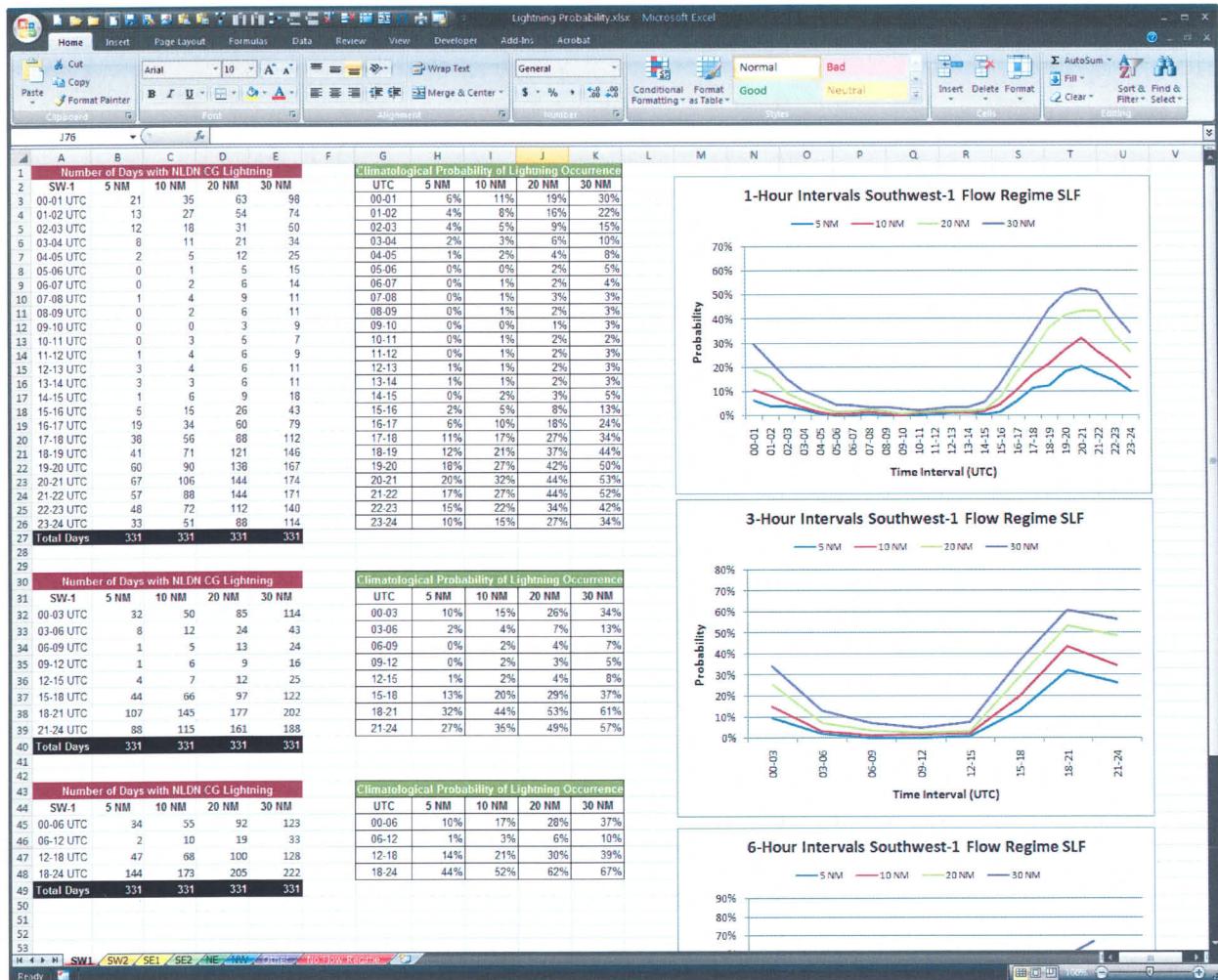


Figure 4. The SLF Excel workbook showing the worksheet for Southwest-1 flow. Tables showing the number of days with lightning and climatological probability of lightning are on the left and center, respectively. The charts corresponding to the probability tables are on the right.

Each site's six workbooks contained 120 probability tables and 120 corresponding charts resulting in a total of 2,160 tables and charts contained within 54 Excel workbook files. Although navigable in Excel, it would be

cumbersome for the operational forecasters to move among the different sites, flow regimes and time intervals. Adding time interval displays to the Excel workbooks would have required generating 27 additional tabs per workbooks for the nine sites. The AMU, NWS MLB and SMG decided a web-based GUI would provide the best tool to allow the forecasters quick and easy access to the data.

4.2 Web-based HTML GUI

The AMU developed a GUI² written in HTML that can be used in most web browsers. The main page of the GUI is shown in Figure 5 and presents the forecaster with an overview map of the nine sites and their range rings plus a navigation menu at the top of the page. The AMU wrote the navigation menu code in the JavaScript language using Microsoft FrontPage software. The main navigation menu is displayed on every page of the GUI and provides the forecaster with one-click access to each site, a page containing a description of the data and flow regime definitions plus navigation back to the **Main Page**. The forecaster can also click within the 5-NM range ring of each site on the map to navigate to the site's main page.

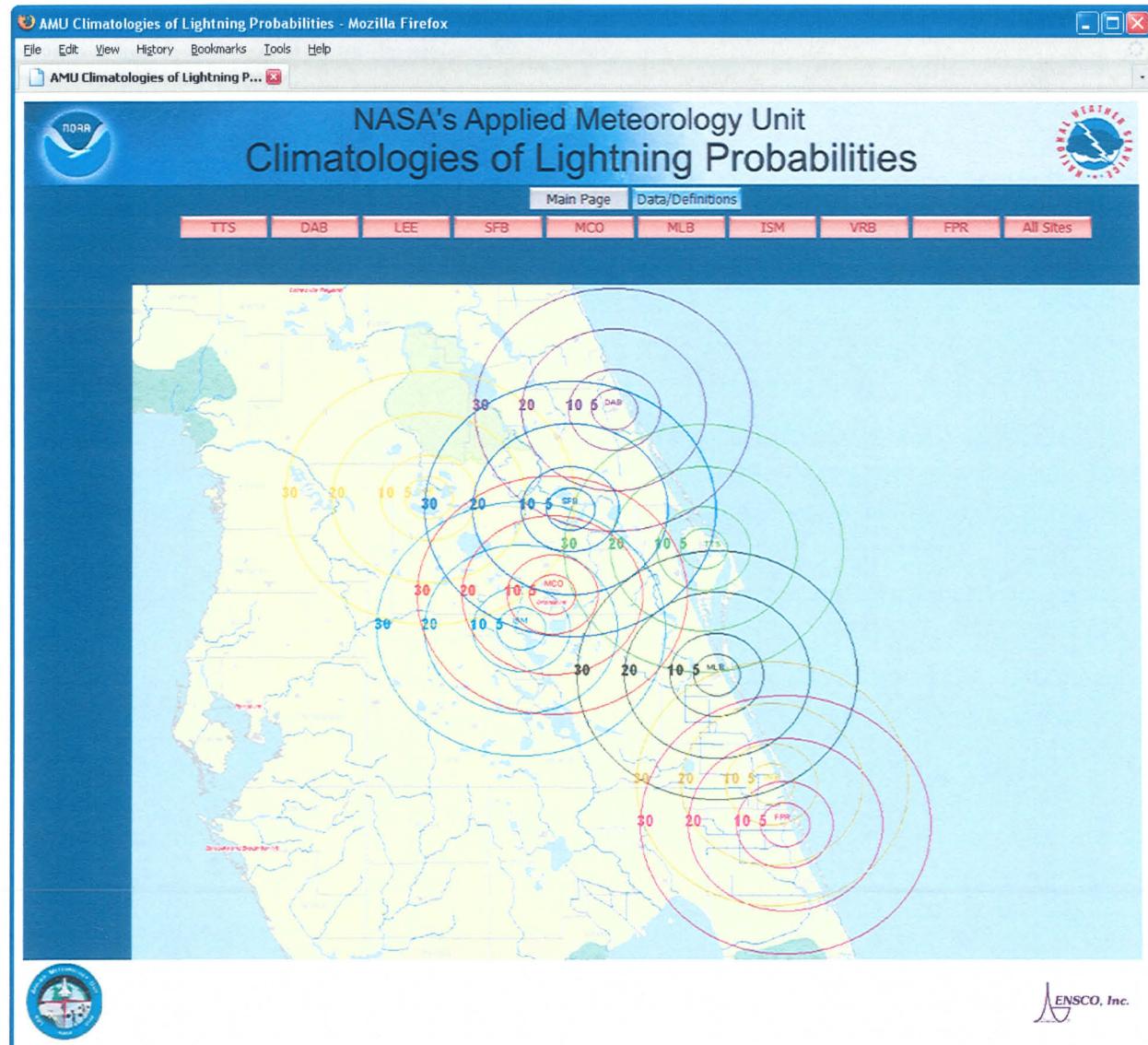


Figure 5. The main page of the Climatologies of Lightning Probabilities GUI displaying a map of the nine sites and main navigation menu (gray, blue and red buttons) at the top of the page.

² The GUI is available by request from the AMU at 321-853-8203 or via e-mail at amu@ensco.com.

Once the forecaster has chosen a site, they are presented with the main page for that site that adds a navigation menu allowing them to choose data for a single month or the entire warm season. Once this choice is made, the forecasters are presented with two additional navigation menus as shown for the SLF (TTS) in Figure 6 which allows them to view the climatological lightning probabilities based on time interval or by flow regime. The main navigation menu and monthly menu remain visible so they can easily switch to another site, view data for a different month or the warm season, access the **Data/Definitions** page or go to the **Main Page**.

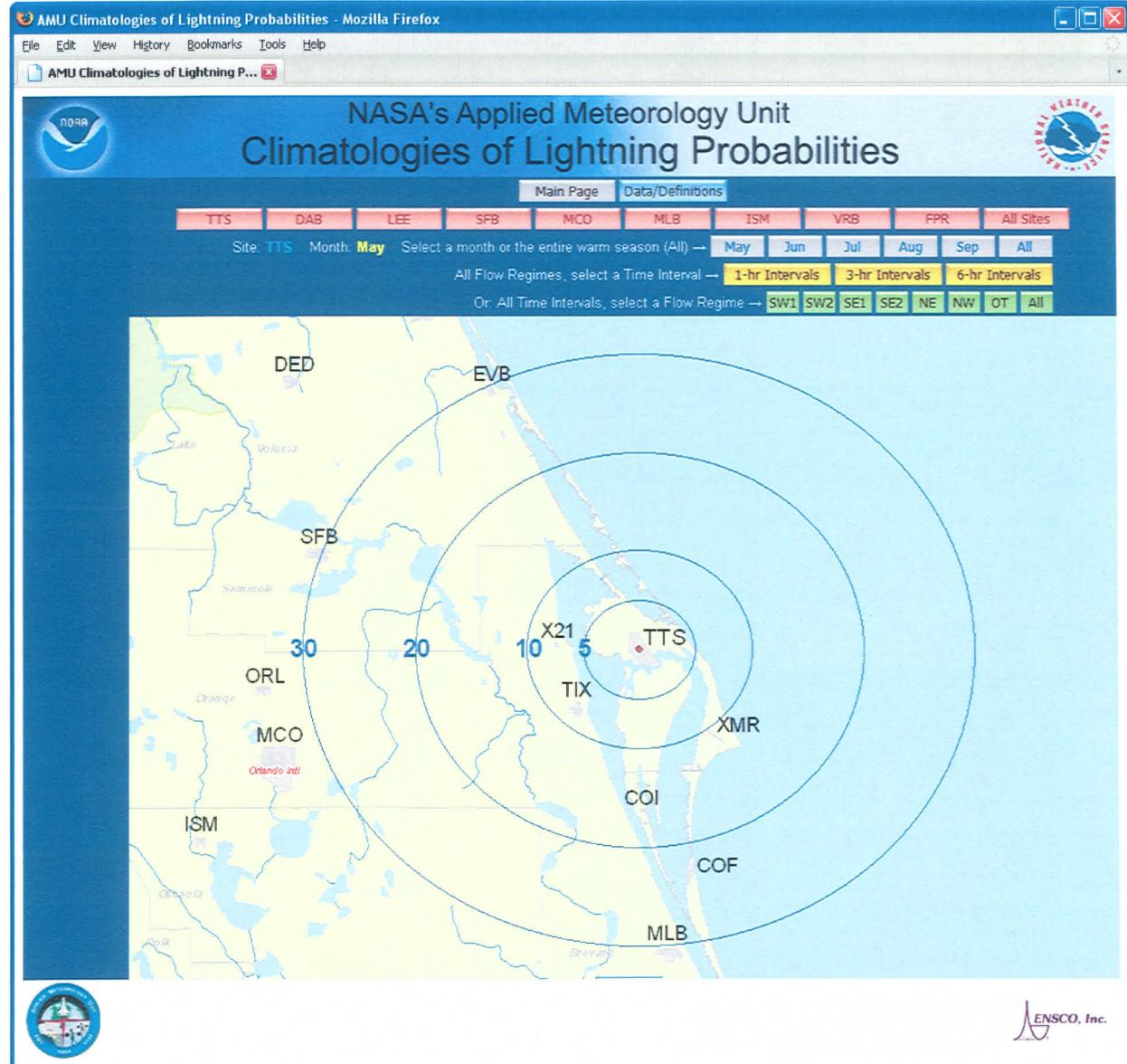


Figure 6. The SLF page showing a map of the site with the range rings displayed, the main navigation menu (gray button with black text, blue and red buttons), monthly navigation menu (gray buttons with blue text), time interval navigation menu (yellow buttons) and flow regime navigation menu (green buttons).

An example of the May 1-hour time interval data for the SLF is shown in Figure 7. The data table of the climatological probability of lightning for each flow regime is presented on the left of the page and the corresponding chart is shown to the right of each table. The forecaster can use the vertical scroll bar to navigate down and up on the page to view the statistics for all eight flow regimes. An example of the data for September under the Northeast flow regime for the SLF is shown in Figure 8. The table of the climatological probability of lightning for each of the three time intervals is presented on the left of the page and the corresponding graph is

shown to the right of each table. The forecaster can use the vertical scroll bar to navigate down and up on the page to view the three time intervals.

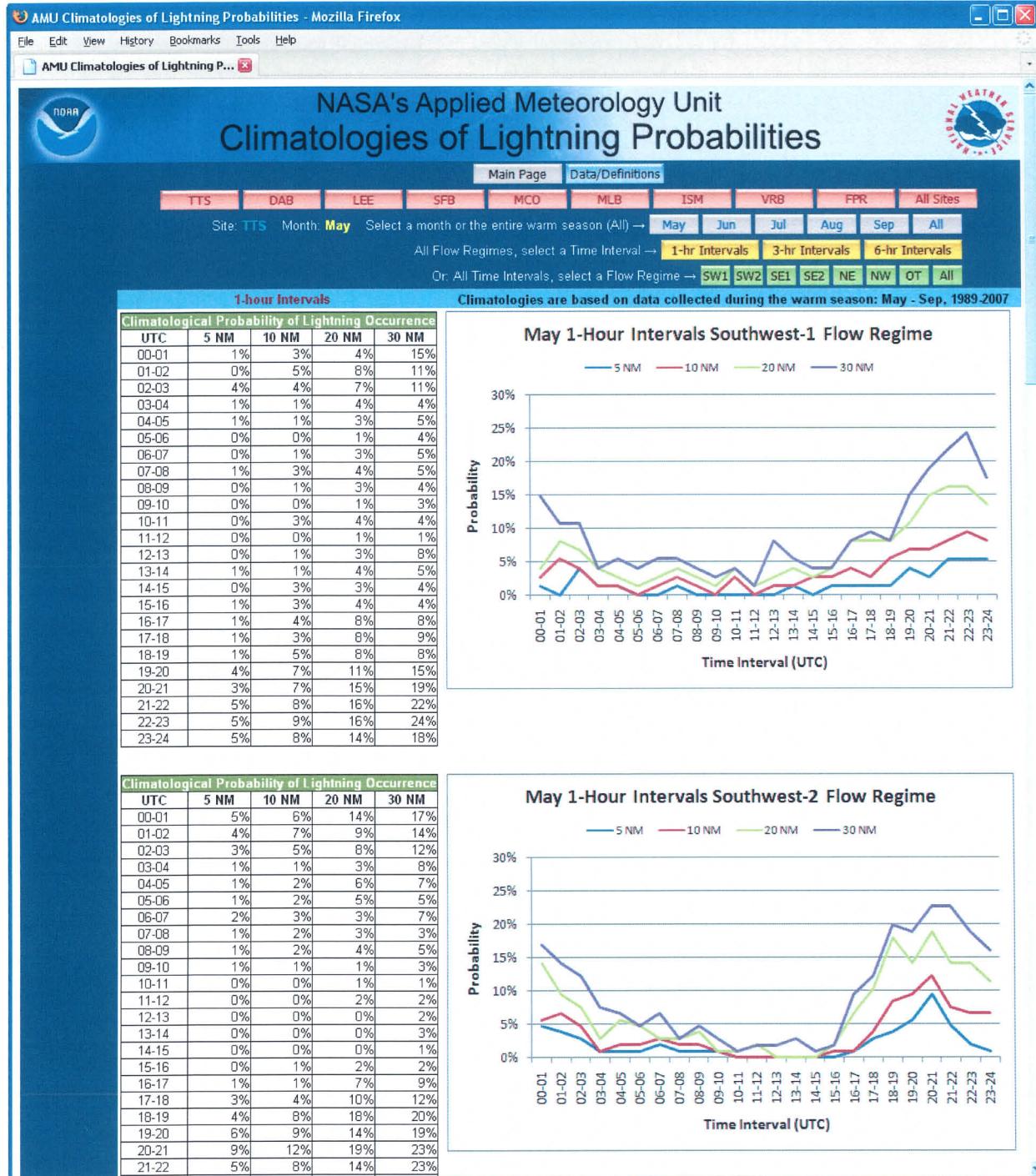


Figure 7. The SLF data for the May 1-hour time intervals and all flow regimes. The data showing the climatological probability of lightning is in tabular form on the left side of the page with corresponding charts to the right of the tables. The forecaster can use the scroll bar on the right to view other flow regimes not shown in this figure. Forecasters can access the entire warm season or other month's data, the other two time intervals or any of the flow regime-based data by clicking on the appropriate button on either of the three sub-navigation menus. The other sites are still accessible from this page from the main navigation menu.

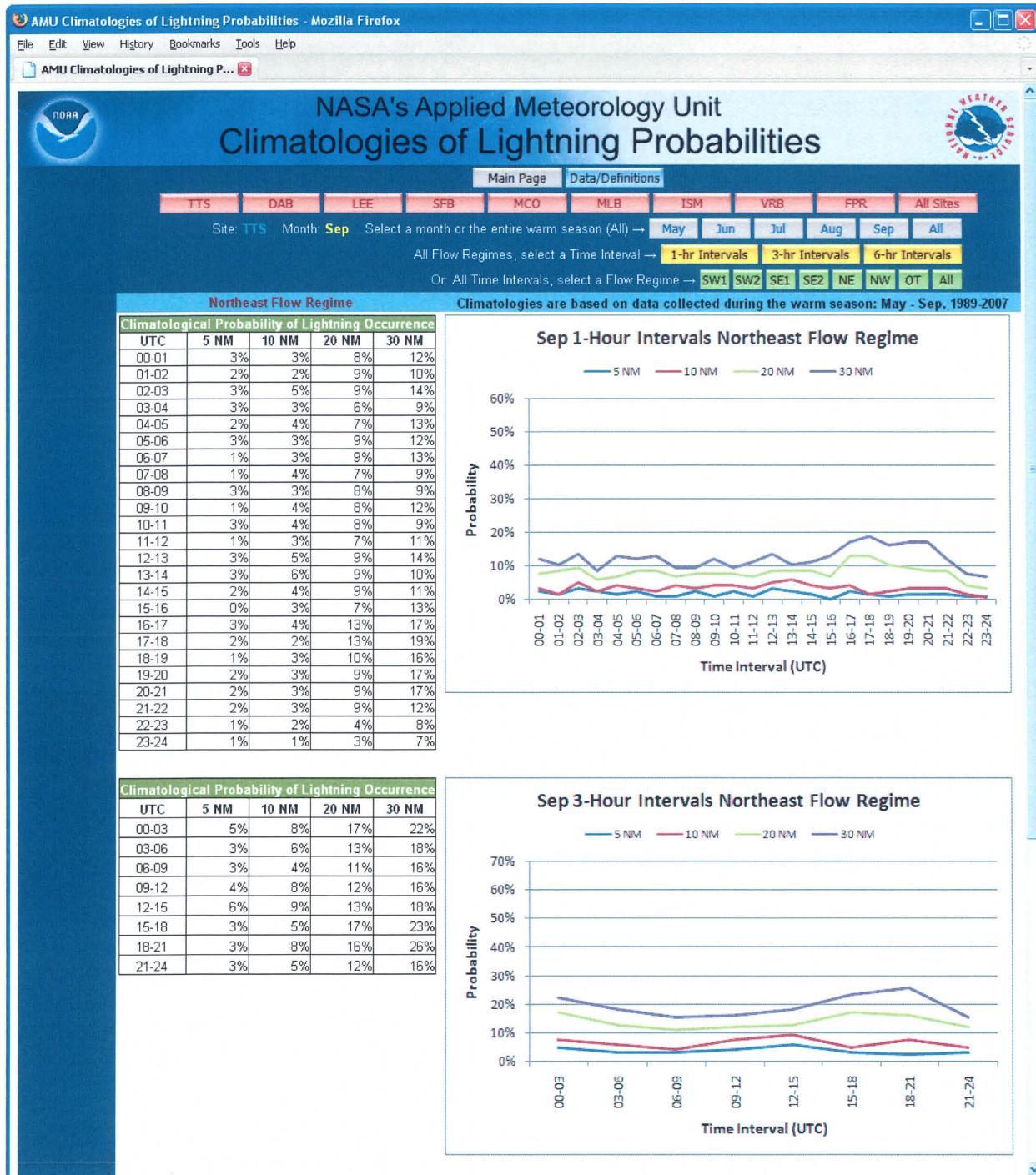


Figure 8. The SLF data displayed for September under the Northeast flow regime and all time intervals. The data showing the climatological probability of lightning is in tabular form on the left side of the page with corresponding charts to the right of the tables. The user can use the scroll bar on the right to view the 6-hour time interval not shown in this figure. Forecasters can access the entire warm season or other month's data, the other seven flow regimes or any of the time interval-based data by clicking on the appropriate button on either of the three sub-navigation menus. The other sites are still accessible from this page from the main navigation menu.

5. Summary and Conclusions

The AMU added three years of data to the POR from the previous work for a total of 19 years (1989-2007) and recalculated lightning climatologies for the SLF and eight airfields in the NWS MLB CWA. NLDN individual lightning strike data were used instead of gridded values to improve the accuracy of the climatologies. The updated climatologies of lightning probabilities are based on revised synoptic-scale flow regimes over the Florida peninsula (Lambert 2007) for 5-, 10-, 20- and 30-NM radius range rings around the nine airfields in 1-, 3- and 6-hour increments. In addition to creating the climatologies based on the flow regimes, the AMU created a stratification based on all the data combined (non-flow regime based) and for each month in the warm season.

The lightning and flow regime data were processed in S-PLUS software using scripts written by the AMU to automate much of the data processing. The S-PLUS data files were exported to Excel to allow the files to be combined in Excel Workbooks for easier data handling and to create the tables and charts for the GUI.

The AMU revised the GUI developed in the previous phase (Bauman 2007) with the new data and provided users with an updated HTML tool to display and manipulate the data and corresponding charts. The tool can be used with most web browsers and is computer operating system independent.

The results of updating the previous phase of this work will produce a better operational product because:

- The POR was increased by three years,
- Individual lightning strike data was used instead of gridded data,
- The range rings were calculated based on radius instead of diameter,
- The climatologies were based on revised, more accurate flow regimes, and
- A monthly stratification was added.

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List of Acronyms

14 WS	14th Weather Squadron	NE	Northeast flow regime
45 WS	45th Weather Squadron	NLDN	National Lightning Detection Network
AMU	Applied Meteorology Unit	NW	Northwest flow regime
CCAFS	Cape Canaveral Air Force Station	NWS MLB	National Weather Service Melbourne, FL
CG	Cloud-to-Ground	POR	Period of Record
DAB	Daytona Beach International Airport	SE	Southeast flow regime
FPR	St. Lucie County International Airport	SFB	Orlando Sanford International Airport
FR	Flight Rules	SLF	Shuttle Landing Facility
GUI	Graphical User Interface	SMG	Spaceflight Meteorology Group
HTML	Hyper-Text Markup Language	SW	Southwest flow regime
ISM	Kissimmee Gateway Airport	TAF	Terminal Aerodrome Forecast
JAX	Jacksonville, FL rawinsonde 3-letter identifier	TBW	Tampa, FL rawinsonde 3-letter identifier
KSC	Kennedy Space Center	TTS	SLF identifier
LEE	Leesburg Regional Airport	VRB	Vero Beach Municipal Airport
MCO	Orlando International Airport	XMR	CCAFS rawinsonde 3-letter identifier
MFL	Miami, FL rawinsonde 3-letter identifier		
MLB	Melbourne International Airport		

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REPORT DOCUMENTATION PAGE					Form Approved OMB No. 0704-0188	
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1. REPORT DATE (DD-MM-YYYY) 30-04-2009		2. REPORT TYPE Final		3. DATES COVERED (From - To) January 2009 - April 2009		
4. TITLE AND SUBTITLE Situational Lightning Climatologies for Central Florida: Phase IV			5a. CONTRACT NUMBER NNK06MA70C			
			5b. GRANT NUMBER			
			5c. PROGRAM ELEMENT NUMBER			
6. AUTHOR(S) William H. Bauman III			5d. PROJECT NUMBER			
			5e. TASK NUMBER			
			5f. WORK UNIT NUMBER			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) ENSCO, Inc. 1980 N. Atlantic Ave Suite 830 Cocoa Beach, FL 32931				8. PERFORMING ORGANIZATION REPORT NUMBER		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) NASA John F. Kennedy Space Center Code KT-C-H Kennedy Space Center, FL 32899				10. SPONSORING/MONITOR'S ACRONYM(S)		
				11. SPONSORING/MONITORING REPORT NUMBER CR-2009-214763		
12. DISTRIBUTION/AVAILABILITY STATEMENT Unclassified, Unlimited						
13. SUPPLEMENTARY NOTES Electronic versions of all Applied Meteorology Unit final reports can be found at http://science.ksc.nasa.gov/amu/final.html						
14. ABSTRACT The threat of lightning is a daily concern during the warm season in Florida. Research has revealed distinct spatial and temporal distributions of lightning occurrence that are strongly influenced by large-scale atmospheric flow regimes. Previously, the Applied Meteorology Unit (AMU) calculated the gridded lightning climatologies based on seven flow regimes over Florida for 1-, 3- and 6-hr intervals in 5-, 10-, 20-, and 30-NM diameter range rings around the Shuttle Landing Facility (SLF) and eight other airfields in the National Weather Service in Melbourne (NWS MLB) county warning area (CWA). In this update to the work, the AMU recalculated the lightning climatologies for using individual lightning strike data to improve the accuracy of the climatologies. The AMU included all data regardless of flow regime as one of the stratifications, added monthly stratifications, added three years of data to the period of record and used modified flow regimes based work from the AMU's Objective Lightning Probability Forecast Tool, Phase II. The AMU made changes so the 5- and 10-NM radius range rings are consistent with the aviation forecast requirements at NWS MLB, while the 20- and 30-NM radius range rings at the SLF assist the Spaceflight Meteorology Group in making forecasts for weather Flight Rule violations during Shuttle landings. The AMU also updated the graphical user interface with the new data.						
15. SUBJECT TERMS Lightning, Climatology, Climatological, Statistics, Probability of Lightning, Space Shuttle, Weather, Meteorology, Shuttle Landing Facility, Flight Rules, Weather Flight Rules, National Weather Service						
16. SECURITY CLASSIFICATION OF: a. REPORT U			17. LIMITATION OF ABSTRACT UU	18. NUMBER OF PAGES 21	19a. NAME OF RESPONSIBLE PERSON Jennifer G. Wilson	
b. ABSTRACT UU					19b. TELEPHONE NUMBER (Include area code) (321) 867-0824	